UNITED STATES PATENT APPLICATION

For

SUPPORT BRA FOR ULTRASONIC BREAST SCANNER

Inventor: Vasilis Z. Marmarelis

Assignee: Alfred E. Mann Institute for Biomedical Engineering at the University of Southern California

MCDERMOTT, WILL & EMERY
2049 Century Park East, Suite 3400
Los Angeles, CA 90067

Attorney Matter No. 64693-073

SUPPORT BRA FOR ULTRASONIC BREAST SCANNER

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is based upon and claims priority to U.S. Provisional Application Serial No. 60/396,516, entitled "Support Bra for Ultrasonic Breast Scanner," filed July 16, 2002, the entire content of which is incorporated herein by reference.

BACKGROUND OF INVENTION

[0002] *Field of Invention*

[0003] This application relates to breast mammography and, more particularly, ultrasonic breast scanners.

[0004] *Description of Related Art*

[0005] Breast mammography has traditionally used x-ray techniques. Unfortunately, x-rays can be harmful to the patient. The breast is also frequently compressed during the procedure. This can create discomfort.

[0006] Ultrasonic scanning has been proposed as an alternate approach. The breast is dangled in a fluid bath. An ultrasonic transmitter and cooperating ultrasonic receiver are rotated around the breast to scan a series of stacked coronal imaging planes. These stacked planes are then used to generate data representative of a three-dimensional image of the breast tissue.

[0007] Unfortunately, the breast may move during the scanning process. This can be caused by turbulence in the fluid and/or by movement of the patient. Such movement can cause blurring of the three-dimensional image. The breast may also secrete fluid creating sanitary issues.

SUMMARY OF INVENTION

[0008] A receptacle for supporting a breast during ultrasonic scanning may include a contoured cup made of material that is substantially transparent to acoustical energy. The cup may have an open end into which the breast may be inserted and a narrowed end configured to receive the nipple of the breast. The receptacle may also have spaced-apart elongated members, each made of material that is not substantially

transparent to acoustical energy and each being mechanically coupled to the open end and to the narrowed end of the cup.

[0009] At least some of the elongated members may be substantially straight. Each substantially straight member may be mechanically coupled to the cup at a point between the open end and the narrowed end. The point may be approximately midway between the open end and the narrowed end.

[0010] Each straight member may be mechanically coupled to the narrowed end by a substantially rigid spacer.

[0011] The scanning may create a set of substantially parallel coronal planes, and each substantially-straight member may be substantially perpendicular to these coronal planes.

[0012] The cup may be substantially symmetrical about an axis and each substantially straight member may be substantially parallel to that axis.

[0013] At least some of the elongated members may be contoured. The contour of each contoured member may be substantially the same as the contour of the cup. Each contoured member may be matingly affixed to the surface of the cup.

[0014] At least some of the elongated members may be substantially straight while other elongated members may be contoured. The cup may be substantially symmetrical about an axis. Each substantially straight member may intersect an end point of a line segment that is perpendicular to and passes through the axis. A contoured member may intersect the other end point of the line segment.

[0015] The number of substantially straight members may equal the number of contoured members. The substantially straight members and the contoured members may be arranged in an alternating sequence.

[0016] The spacing between each neighboring pair of elongated members may be substantially equal.

[0017] A receptacle for supporting a breast during ultrasonic scanning may include a contoured cup configured to snuggly fit over the breast without stretching significantly.

The cup may be made of a material that does not leak fluid and is substantially transparent to acoustical energy.

[0018] The contoured cup may include an elastic polymer. The elastic polymer may include latex.

[0019] An acoustically conductive material may be placed on the inside of the cup. The acoustically conductive material may include a viscous gel.

[0020] A receptacle for insertion through an opening in an ultrasonic scanner and for supporting a breast during scanning may include a contoured cup made of material that is substantially transparent to acoustical energy that has an open end into which the breast may be inserted and a narrowed end configured to receive the nipple of the breast. The receptacle may also include an annular ring mechanically coupled to the open end of the cup and configured to releasably engage the opening in the ultrasonic scanner.

[0021] The annular ring may have a surface that is substantially perpendicular to the contour of the cup at the open end.

[0022] The diameter of the open end of the cup may be slightly less than the diameter of the opening in the ultrasonic scanner and the outer diameter of the annular ring may be greater than the diameter of the opening in the ultrasonic scanner.

[0023] The annular ring may be flat.

[0024] An ultrasonic scanner for scanning a breast may include a rotatable mechanism configured to rotate around the breast. It may also include at least one ultrasonic transducer mechanically coupled to the rotatable mechanism. It may also include a pump configured to cause fluid to flow across the surface of the breast, or across a contoured cup in which the breast is inserted, from approximately the portion of the breast that is closest to the chest to approximately the nipple of the breast, as the rotatable mechanism rotates.

[0025] The pump may include a rotatable chamber and a substantially helical groove on the inner wall of the rotatable chamber.

[0026] An ultrasonic scanner for scanning a breast may include a rotatable chamber configured to rotate around the breast. The scanner may include at least one ultrasonic transducer mechanically coupled to the rotatable mechanism that has an acoustic impedance. The scanner may include fluid within the rotatable chamber, a contoured cup configured to contain the breast, and gel on the inside of the cup, all having an acoustic impedance substantially the same as the ultrasonic transducer.

[0027] These as well as still further features, objects and benefits will now become clear upon an examination of the following Detailed Description of Illustrative Embodiments and the attached drawings.

BRIEF DESCRIPTION OF DRAWINGS

[0028] FIG. 1 shows portions of an ultrasonic scanner with a support bra and contoured coronal plane locator wires.

[0029] FIG. 2 shows a support bra with straight and contoured coronal plane locator wires.

[0030] FIG. 3 is a top view of FIG. 2.

[0031] FIG. 4 is a sectional view of a rotatable chamber using a helical groove as a fluid pump.

[0032] FIG. 5 illustrates a contoured tabletop that may be used in an ultrasonic scanner.

DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0033] FIG. 1 shows portions of an ultrasonic scanner with a support bra and contoured coronal plane locator wires.

[0034] As shown in FIG. 1, a tabletop **101** on which a female patient may lie may include an opening **103** into which a bra-like receptacle **105** may be inserted. Directly below the opening **103** may be a stationary chamber **107**.

[0035] The tabletop **101** may be long enough and wide enough to accommodate varies sizes of female patients. Similarly, the opening **103** may be large enough to accommodate various sizes of breasts that will be placed within it. A reduction ring (not

shown) may be inserted in the opening **103** to better support female subjects with smaller breasts.

[0036] The receptacle **105** may include a contoured cup **125** attached to an annular ring **127**.

[0037] The contoured cup **125** may include an open end **129** into which the breast may be inserted and a narrowed end **131** into which the nipple of the breast may be inserted.

[0038] The contoured cup **125** may be made of material that is transparent to acoustical energy, such as an elastic polymer, such as latex.

[0039] The contoured cup may be of a size that snugly fits the breast without having to stretch significantly to accommodate the breast, thus minimizing the degree to which the contoured cup **125** compresses the breast. In practice, this may require different sizes of the contoured cup **125** to be produced and made available, so that different sizes of breasts may be correctly fitted.

[0040] The annular ring **127** that is affixed to the contoured cup **125** may be a flat surface that is substantially perpendicular to the upper wall of the contoured cup **125**. It may have an inner diameter that is smaller than the diameter of the opening **103** and an outer diameter that is larger than the diameter of the opening **103**. Using this configuration, the receptacle **105** can easily be inserted within the opening **103** and allowed to have its annular ring **127** rest on the top of the table **101**. After being used, the receptacle **105** can be removed from the opening **103** and, if desired, discarded or cleaned. A new or cleaned receptacle **105** can then be easily used for the next subject.

[0041] Before the breast is inserted in the contoured cup **125**, the inner wall of the contoured cup **125** may be coated with a gel. The gel may be acoustically conductive. The gel may be spread on all inner surfaces of the cup **125** to insure that there are no air pockets between the breast and the contoured cup **125**. The gel may also be viscous to insure that the breast does not move with respect to the contoured cup **125** during the scanning process.

[0042] Within the stationary chamber **107** may be a rotatable chamber **109** to which may be affixed an ultrasonic transmitter **111** and an ultrasonic receiver **113**.

[0043] The ultrasonic transmitter **111** may consist of only a single element or may include an array of elements. Similarly, the ultrasonic receiver **113** may consist of only a single element or may include an array of elements.

[0044] Both the stationary chamber **107** and the rotatable chamber **109** may be filled with a fluid **119**. The contoured cup **125** may be completely sealed to prevent fluid excreted by the breast from mixing with the fluid **119**.

[0045] The fluid **119** may be of a type that provides acoustic coupling. It may also be of low viscosity to minimize turbulence during rotation of the rotatable chamber **109**. Water is one example of a fluid that may be used.

[0046] The materials used for the fluid **119**, the contoured cup **125** and the gel may be selected so that their acoustic impedances closely match the acoustic impedances of the ultrasonic transmitter **111** and the ultrasonic receiver **113**.

[0047] The impedance of normal breast tissue may be significantly different from the acoustic impedances of the ultrasonic transmitter **111** and the ultrasonic receiver **113**. In this event, the materials used for the fluid **119**, the contoured cup **125** and the gel may be selected so as to have acoustic impedances that bridge the impedance difference between the ultrasonic transducers and the normal breast tissue in successive steps.

[0048] Appropriate fluid filling and drainage mechanisms (not shown) may be employed to fill the chambers **107** and **109** with fluid, in preparation for ultrasonic scanning, and to then remove the fluid after scanning.

[0049] The filling mechanism (not shown) may deliver sufficient fluid to cause the level of the fluid in the stationary chamber **107** to exceed the level of the ultrasonic transmitter **111** and ultrasonic receiver **113**. Holes (not shown) may be placed in the walls of the rotatable chamber **109** to allow fluid to freely flow between the rotatable chamber **109** and the stationary chamber **107**. The inner walls of the rotatable chamber **109** may be configured to minimize turbulence during its rotation.

[0050] The rotatable chamber **109** may be affixed to a shaft **115** that extends beneath the stationary chamber **107** through a fluid tight bearing seal **117**.

[0051] The rotatable chamber **109** may be rotated around the receptacle **105**, as reflected by a rotational movement arrow **121**. It may also be lowered during the scanning process, as reflected by a longitudinal movement arrow **123**. These movements may be accomplished by the application of appropriate forces to the shaft **115** by an appropriate drive mechanism (not shown).

[0052] The exact motion imparted to the shaft **115** and, in turn, to the rotatable chamber **109** can vary. In one application, the scanning process may begin by the rotatable chamber **109** being raised to its highest position such that the top of the ultrasonic transmitter **111** and the top of the ultrasonic receiver **113** are as high as possible without scraping the underneath side of the tabletop **101**. The shaft **115** may then be rotated to cause the rotatable chamber **109** to rotate 360 degrees.

[0053] During this rotation, an ultrasonic signal may be directed from the ultrasonic transmitter **111** through the fluid **119**, the receptacle **105** and the breast that is within the receptacle, until it received by the ultrasonic receiver **113**. Data representing a two dimensional, coronal image plane cross-section of the breast may then be gathered.

[0054] After this first coronal plane is scanned, the drive mechanism (not shown) to which the shaft **115** is attached may incrementally lower the shaft, causing a corresponding incremental lowering of the rotatable chamber **109**. The drive system may then rotate the shaft **115** through another 360 degrees, causing a second coronal plane to be scanned. The process may then repeat until all of the breast has been scanned.

[0055] Shaft **115** may instead be continually lowered while it is being rotated, resulting in a helical scan.

[0056] Regardless of which approach is used, the stacked coronal imaging planes may then be analyzed in accordance with well known techniques to generate data that represents a three-dimensional image of the tissue in the breast.

[0057] Coronal plane locators **135** may also be used. The locators **135** may each include an elongated member affixed at its upper end to the edge of the opening **129** in the contoured cup **125**. They may also be affixed at their lower end to the narrowed portion **131** of the contoured cup **125**. They may also be affixed at some or all of the points in between to the contoured cup **125**. The locators **135** may also be contoured to match the contour of the contoured cup **125**.

[0058] The locators **135** may be of material that is substantially opaque to ultrasonic signals. For example, the locators **135** may be thin metal wires.

[0059] The locators **135** may be spaced apart. They may be equally spaced around the perimeter wall of the contoured cup **125**, such as the 120-degree spacing shown in FIG. 1.

[0060] Although three locators **135** are shown in FIG. 1, it is to be understood that a different number could be used instead, such as two or four.

[0061] The acoustically opaque nature of the locators **135** will cause them to appear in each coronal imaging plane. In turn, their presence in all of the coronal imaging planes can be used by the processing system (not shown) to aid in the co-registration of these planes. These location points may also aid in correcting any errors caused by motion of the breast during the scanning process. An auto-focusing processing algorithm, such as is used in synthetic aperture radar (SAR), may be used for this purpose.

[0062] FIG. 2 shows a support bra with straight and contoured coronal plane locator wires. FIG. 3 is a top view of FIG. 2.

[0063] As shown in FIGS. 2 and 3, elongated contoured locators **201** may be used. These may be just like the locators **135** that were discussed above in connection with FIG. 1.

[0064] Elongated straight locators **203** may also be used. These may similarly be attached at one end to the perimeter of the opening **205** of the contoured cup **207** and, at their other end, to the narrowed end **209** of the contoured cup **207**. The attachment of the straight locators **203** at their lower end to the narrowed portion **209** of the contoured cup **207** may be facilitated by a substantially rigid spacer, such as the radial arms **211**.

[0065] As with the contoured locators **135** shown in FIG. 1, the contoured locators **201** shown in FIGS. 2 and 3 may be evenly spaced around the perimeter of the opening **205**. Similarly, straight locators **203** may be evenly spaced around the perimeter of the opening **205**.

[0066] As perhaps most clearly illustrated in FIG. 3, the locators around the perimeter of the opening **205** may alternate between a contoured locator **201** and a straight locator **203**. The upper end of each straight locator **203** may be on a line segment **213** that passes through the symmetric axis **215** of the contoured cup **207**, while the upper end of a curved locator **201** may be attached to the other end of that line segment. The straight locators **203** may also be attached at their approximate midpoints to the contoured cup **207**.

[0067] As with the contoured locators **125** in FIG. 1, there can be any number of contoured locators **201** and straight locators **203** in FIGS. 2 and 3. Although shown as having both straight and contoured locators, it is also to be understood that the receptacle may include only contoured locators, as shown in FIG. 1, only straight locators, or no locators.

[0068] As with the contoured locators **135** in FIG. 1, the contoured locators **201** and/or the straight locators **203** in FIGS. 2 and 3 may be used to aid in co-registering the stacked coronal planes that result from the scan.

[0069] FIGS. 4 is a sectional view of a rotatable chamber using a helical groove as a fluid pump. As shown in FIG. 4, a rotatable chamber **401** may have affixed at its top an ultrasonic transmitter **403** and an ultrasonic receiver **405**. A shaft **407** may be affixed to the rotatable chamber **401** and may be controlled as described above in connection with the shaft **115** in FIG. 1.

[0070] The rotatable chamber **401** may include a helical groove **409** in its inner wall. When the rotatable chamber **401** is filled with fluid and rotates, the rotating chamber **401** may cooperate with the helical groove **409** to act like a pump and can cause fluid within the chamber to swirl in a manner that causes the fluid to flow from the portion of the cup **411** that is closest to the chest of the patient to the portion of the cup **413** that is in the area of the nipple of the breast, as reflected by fluid flow arrows **415**. This may

help stabilize the breast during the scanning process. The fluid pumping action may also be used in systems in which the breast is inserted without a bra-like receptacle.

[0071] Other types of fluid pumps may be used instead, such as a pump that is external to the rotatable chamber **401** that delivers fluid into the rotating chamber and in a manner that similarly swirls downwardly across the breast, as shown by the fluid flow arrows **415**.

[0072] FIG. 5 illustrates a contoured tabletop that may be used in an ultrasonic scanner. As shown in FIG. 5, a tabletop **501** containing an opening **505** in which a receptacle **507** is inserted. The tabletop **501**, opening **505** and receptacle **507** may be governed by the same considerations that were discussed above in connection with the tabletop **101** opening **103** and receptacle **105** shown in FIG. 1.

[0073] The tabletop **501** may also include a contoured section **503**. The contour of the contoured section **503** may substantially match the contour of the average chest of the patient that lies on top of it. This may increase the comfort to the patients and help insure that the breast of each patient is always inserted through the opening **505** in the same X-Y orientation, thus insuring consistency in the orientation of the tissue images that are developed.

[0074] Having now described illustrative embodiments, those skilled in the art will appreciate that modifications may be made to them without departing from the spirit of the concepts that are embodied in them. Further, it is not intended that the scope of this application be limited to these specific embodiments or to their specific features or benefits. Rather, it is intended that the scope of this application be limited solely to the claims which now follow and to their equivalents.